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RTHROP AIRCRAFT INC.

Progress Report

NORTHROP AIRCRAFT, INC.
HAWTHORNE, CALIFORNIA

CONTRACT Nonr-775

RESEARCH ON HIGH LIFT BOUNDARY LAYER SUCTION
INVESTIGATIONS ON THIN HIGH SPEED WINGS

Report to:
Office of Naval Research
For period ending 28 February 1952

NORTHROP FIELD
HAWTHORNE, CALIF.

NORTHROP

CONFIDENTIAL

PROGRESS REPORT

NORTHROP AIRCRAFT, INC.

HAWTHORNE, CALIFORNIA

CONTRACT Nonr-775(00)

RESEARCH ON HIGH LIFT BOUNDARY LAYER SUCTION INVESTIGATIONS ON THIN HIGH SPEED WINGS

Report to:

OFFICE OF NAVAL RESEARCH

For Period Ending 28 February 1953

Prepared by:

BOUNDARY LAYER RESEARCH PROJECTS OFFICE

INDEX

NORTHROP AIRCRAFT, INC.

PROGRESS REPORT - RESEARCH ON HIGH LIFT BOUNDARY LAYER SUCTION
INVESTIGATIONS ON THIN HIGH SPEED WINGS

CONTRACT Nonr-775(00)

I. BRIEF OF CONTRACT

A. Financial

Estimated Contract Value	$74,719
Expenditure to 28 February 1953	55,038
Unexpended Balance	$19,681

To insure continuance of this program, which at present is approximately 55 per cent complete, NAI letter 8400-53-67 dated 13 January 1953 was sent to the Office of Naval Research requesting additional funds and extension of time to 31 August 1953. Technical data outlining accomplishments to date, present plans for funds remaining, and plans for funds requested are in process of preparation for submittal to the Navy Project Officer through NAI's Washington representative.

B. Basic Contract

Supply the necessary personnel and facilities for, and in accordance with, any instructions issued by the Scientific Officer or his authorized representative; conduct research on high lift boundary layer and circulation suction calculations and experiments with thin swept wings.

II. TECHNICAL PROGRESS

A. Theoretical Investigations

I. Boundary Layer Control at the Leading Edge of a Thin High Lift Suction Wing Without Leading Edge Flaps

On a thin airfoil without deflected leading edge flap, high local velocities and low negative pressure peaks develop at large c_L on the upper surface at the leading edge. In order to delay leading edge separation to higher c_L, boundary layer control should be applied on the upper surface in the region of the adverse pressure gradient within the first few per cent of the chord.

Boundary layer calculations at Northrop have shown that basically it should be possible to maintain laminar flow at large c_L through the region of this adverse pressure gradient on a thin high lift suction wing by means of boundary layer suction with extremely small suction quantities. On a straight 2-dimensional NACA 0006-64 section with a 60° to 70° deflected trailing edge suction flap $c_{L\,max} \cong 3.5$ could be expected with a suction quantity at the leading edge of $C_Q = \frac{Q_a}{U_o S} = 2,5 \cdot 10^{-4}$ at a chord Reynolds number of 10^7. The question arises as to how the theoretical estimates have been verified by the experiment.

High lift suction experiments at Ames on an F86 wing with continuous suction at the leading edge (Reference 1) have shown considerably larger suction quantities than laminar boundary layer theory indicates. Considerable effort was therefore spent in explaining the discrepancy between theory and experiment. Laminar suction experiments in a narrow channel with continuous suction as well as with suction through slots (References 2, 3, and 4) confirm that laminar flow can be maintained through a considerable pressure rise by means of suction with approximately the theoretical suction quantities. In these experiments the velocity distribution along the channel at the edge of the boundary layer was very similar to that around the leading edge of a high lift suction airfoil at high c_L. It is therefore doubtful whether the boundary layer on the F86 wing had actually been laminar in the suction region.

Premature transition might have been caused on the F86 wing for the following reasons. It was suspected that spanwise flow on the F86 wing might have influenced transition: British experiments (References 5 and 6) have shown that sweep can easily cause premature transition by the formation of dynamically unstable boundary layer profiles in the direction normal to the streamline at the edge of the boundary layer (Reference 7). Laminar boundary layer calculations at Northrop of the spanwise flow, however, indicate that spanwise flow should not have influenced to any extent the stability and transition of the laminar boundary layer at the leading edge of the F86 wing during the high lift suction tests at Ames. Experiments at the National Physical Laboratory and at Northrop on a rotating disc, confirmed that the local Reynolds number of the spanwise flow at the leading edge of the F86 wing was probably too low to induce premature transition (on a rotating disc the radial boundary layer profiles ((Reference 8)) show the same type of instability as the boundary layer on a swept wing in the region of a pressure gradient).

Another reason for premature transition on the F86 wing might have been excessive surface roughness and waviness in the suction region at the leading edge. Since the boundary layer is very thin at the leading edge, surface roughness is particularly critical. At high c_L the surface roughness at the leading edge of the F86 wing during the Ames experiments was approximately as critical as on a laminar flow wing of 5-ft chord at $20 \cdot 10^6$ to $25 \cdot 10^6$ chord Reynolds number at the design lift coefficient. It is strongly suspected that excessive surface roughness and waviness has caused premature transition on the F86 wing in the suction region, thus requiring considerably stronger suction than with a laminar boundary layer.

An interesting possibility has been found for conducting basic laminar suction experiments in a relatively simple manner at the leading edge of a high lift suction airfoil under full scale conditions. The potential flow pressure distribution calculations on various high lift suction wings of different thickness ratios and the same thickness distribution curves are obtained by plotting the static pressures versus

$$\frac{\left(\frac{X}{C}\right)}{\left(\frac{R_o^2}{C}\right)},$$

starting from the same minimum pressure peak. (X = coordinate in chordwise direction, R_o = leading edge radius, C = wing chord). For example, the local flow conditions around the leading edge of a 0006-64 high lift suction wing are approximately the same as those around a 0012-64 high lift suction wing with a four times smaller wing chord (assuming the same tunnel speed). This means that leading edge boundary layer control can be studied under full scale conditions on relatively small models and in smaller wind tunnels by using models with a larger percentage thickness ratio and leading edge radius.

Leading edge boundary layer suction can be accomplished through a porous surface or through several fine slots. A well designed continuous suction through a porous surface is aerodynamically slightly superior than suction through several slots. However, the larger surface roughness and waviness of a porous surface may easily compensate its slight aerodynamic advantage.

2. Boundary Layer Control (suction or blowing) in the Region of the Flap Axis of a Deflected Leading and Trailing Edge Flap

From the standpoint of $c_{L\ max}$ a thin high lift suction wing with deflected leading and trailing edge flap and boundary layer control (suction or blowing or combination of both) in the region of the flap axis (front and rear flap) seems promising. Calculations of the turbulent boundary layer development on thin high lift suction wings indicate that relatively small suction quantities should enable attached turbulent flow over the trailing edge flap at high c_L. ($C_Q \cong 0.005$ ((single slot)) and 0.002 to 0.003 ((continuous suction)) at the rear flap axis for 0006-64 section with 60° deflected trailing edge flap.)

With continuous suction of a turbulent boundary layer, the turbulent mixing within the boundary layer in the suction region is probably considerably stronger than with suction in a single slot for the same pressure rise across the suction region. Therefore, smaller suction quantities should be expected with continuous suction than with a single slot. Continuous suction can be approached by suction through a porous surface or through a relatively large number of fine slots or through a large number of fine holes.

Very probably, continuous suction at the flap axis is more favorable from the standpoint of hysteresis than suction through a single slot. Furthermore, suction through single slots with well shaped slot diffusers may be unstable under certain conditions. (The static pressure in the suction chambers may increase with increasing suction quantities within a certain suction range ((Reference 9)). Since continuous suction of a turbulent boundary layer in the region of the flap axis seems more favorable than suction through a single slot from the standpoint of suction quantity, hysteresis, and stability, it is intended to concentrate particularly on continuous suction (porous surface, several fine slots, rows of fine holes).

3. Pressure Distribution Calculations

A report describing the results of potential flow pressure distribution calculations on thin high lift suction airfoils is being completed.

B. Experimental Investigations

The design of a swept half span high lift suction wing model is continuing. Additional preliminary slot diffuser experiments have been conducted in order to check some previous tests.

III. PHYSICAL COMPLETION

	Estimated Weight Factor	Estimated Percent Complete	Estimated Physical Completion
Theoretical Investigations	40	95	38
Model Design	20	80	16
Model Fabrication	20	0	0
Experimental Investigation	20	5	1
	100%		55%

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